

REMARKS

This Preliminary Amendment cancels, without prejudice, originally-filed claims 1-34 in underlying PCT Application No. PCT/DE00/02012. New claims 35-70 have been added merely to conform the claims to U.S. Patent and Trademark Office practice and standards, and do not add new matter to the application. Furthermore, the addition of these new claims in no way addresses any issues of patentability, and the new claims are provided to place the application in condition for allowance.

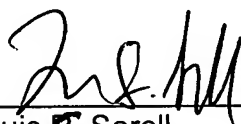
The amendment to the abstract and the substitute specification are provided to correct grammatical and syntactical errors and otherwise to conform the specification and abstract of the above-identified application to the U.S. Patent and Trademark Office practice. No new matter has been introduced to the application.

The amendments to the "Claims" is reflected in the attached "Version With Marked Changes Made."

Favorable consideration on the merits is respectfully requested.

Respectfully submitted,

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**Version With Marked Changes Made**

**WE CLAIM:**

35. 1.—An electromechanical connection between electronic circuit systems (10) and substrates (20), in which ~~an~~comprising the electronic circuit system (10) and a substrate (20) are mechanically connected ~~fixedly~~ to one another, and electrical connection elements (11, 21) which face one another on the electronic circuit system (10) and the substrate (20) are in each case connected in an electrically conductive manner by means of microcapsules (23-1, 23-2), and in which the microcapsules (23-1, 23-2) are formed ~~by~~from grains (23-1) which are coated with a dielectric (23-2) and which are at least ~~in part~~ are partially electrically conductive, characterized ~~in that~~wherein the dielectric (23-2) of the microcapsules (23-1, 23-2) is broken open at least on its ~~areas~~ which face the electrical connection elements (11, to 21), ~~and at the~~ correspondingly provide exposed areas of the grains, (23-1) and an electrically conductive soldered joint (25 ~~to~~ 28) is formed ~~in each case~~ between the exposed areas of the grains (23-1) and the electrically conductive connection elements (11, 21), which in each case face these areas, of the electronic circuit system (10) and of the substrate (20), respectively.

36. 2.—The electromechanical connection as ~~claimed in~~according to claim 1, characterized ~~in that~~35, wherein the ~~mechanically fixed~~mechanical connection between the electronic circuit system (10) and substrate (20) is made by means of an adhesive (24).

37. 3.—The electromechanical connection as ~~claimed in~~ claims 1 and 2, characterized ~~in that~~according to claim 36, wherein the adhesive (24) ~~used is~~ is formed from a polymer.

38. 4.—The electromechanical connection as ~~claimed in~~ one of claims 1 to 3, characterized ~~in that~~according to claim 36, wherein the microcapsules (23-1, 23-2) are embedded in the adhesive (24).

39. 5-~~The electromechanical connection as claimed in~~according to claim 1, ~~characterized in that~~35, wherein the ~~mechanically fixed~~mechanical connection between electronic circuit system (10) and substrate (20) is formed by a soldered joint between connection elements (11, 21) which are inactive in the intended electronic functioning of electronic circuit system (10) and substrate (20).

40. 6-~~The electromechanical connection as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains (23-1) which are selected from the group of metals consisting of copper, nickel, silver, and gold and are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2).

41. 7-~~The electromechanical connection as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains (23-1) of a solderable metal alloy, ~~which are covered with a dielectric (23-2), are used as microcapsules (23-1, 23-2).~~

42. 8-~~The electromechanical connection as claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are metallized; insulating grains (23-1) which are covered with a dielectric (23-2) are used as microcapsules (23-1, 23-2).

43. 9-~~The electromechanical connection as claimed in~~according to claim 8, ~~characterized in that~~42, wherein the grains are silver-plated tin oxide grains ~~are used as metallized, insulating grains (23-1).~~

44. 10-~~The electromechanical connection as claimed in one of claims 6 to 9, characterized in that~~according to claim 35, wherein the dielectric is an insulating enamel ~~is used as the dielectric (23-2) of the microcapsules (23-1, 23-2).~~

45. 11.—The electromechanical connection as ~~claimed in claim 10, characterized in that a~~  
~~soldering flux is used as~~according to claim 44, wherein the insulating enamel is a soldering flux.

46. 12.—The electromechanical connection as ~~claimed in one of claims 1 to 11,~~  
~~characterized in that~~according to claim 35, wherein the electrically conductive soldered joint (25  
to 28) between the connection elements (11, 21) of ~~electronic circuit system (10) and substrate~~  
(20) is formed by ~~soldering of~~ layers of solder (25, 27) which are provided on the connection  
elements (11, 21) to form intermetallic phases (26, 28) comprising material of the electrically  
conductive grains (23-1) of the microcapsules (23-1, 23-2) and the layers of solder (25, 27).

47. 13.—The electromechanical connection as ~~claimed in~~according to claim 12,  
~~characterized in that~~46, wherein a metal selected from the group consisting of ~~tin~~, indium and  
gallium is used as the material for the layers of solders (25, 27).

48. 14.—The electromechanical connection as ~~claimed in~~according to claim 12,  
~~characterized in that~~46, wherein a metal alloy ~~with~~having a low melting point is used as the  
material for the layers of solder (25, 27).

49. 15.—The electromechanical connection as ~~claimed in~~according to claim 13 or 14,  
~~characterized in that~~47, wherein the layers of solder (25, 27) ~~are~~comprise layers of tin which have  
been deposited selectively and ~~without using~~the use of an electric current.

50. 16.—The electromechanical connection as ~~claimed in one of claims 1 to 15,~~  
~~characterized in that~~according to claim 35, wherein the electrical connection elements comprise a  
metallic material which is matched to the metallic material of the conductive grains (23-1) of the  
microcapsules (23-1, 23-2) ~~is used as material for the connection elements (11, 21) of electronic~~  
circuit system (10) and substrate (20).

51. 17.—The electromechanical connection as ~~claimed in claim 16, characterized in that~~according to claim 50, wherein (23-1) of the microcapsules (23-1, 23-2) is used as material for the connection elements (11, 21) of electronic circuit system (10) and substrate (20) comprise a metal selected from the group consisting of copper or and nickel is used as material for the connection elements (11, 21).

52. 18.—The electromechanical connection as ~~claimed in one of claims 1 to 17, characterized in that~~according to claim 35, wherein the microcapsules are provided in a single layer, of said microcapsules (23-1, 23-2) being of a uniform size and embedded in a polymer film are provided.

53. 19.—The electromechanical connection as ~~claimed in one of claims 1 to 5, characterized in that~~according to claim 35, wherein the grains are electrically conductive metal grains (23-1) which are covered with an insulating enamel (23-2) and, which grains at least in part consist of a solder metal are used as microcapsules (23-1, 23-2).

54. 20.—The electromechanical connection as ~~claimed in~~according to claim 19, characterized in that53, wherein the electrically conductive grain (23-1) of the microcapsules (23-1, 23-2) consist entirely of solder metal.

55. 21.—The electromechanical connection as ~~claimed in~~according to claim 19 or 20, characterized in thata53, wherein the solder metal is selected from the group consisting of tin, indium, and gallium ~~is used for the electrically conductive grains (23-1).~~

56. 22.—The electromechanical connection as ~~claimed in claim 19 or 20, characterized in that~~according to claim 53, wherein the solder metal is a soft-solder alloy is used for the electrically conductive grains (23-1).

57. 23.—The electromechanical connection as ~~claimed in one of claims 19 to 22,~~  
~~characterized in that~~according to claim 53, wherein a solderable metal is used for the connection  
elements ~~(11, 21)~~ of electronic circuit system ~~(10)~~ and substrate ~~(20)~~.

58. 24.—The electromechanical connection as ~~claimed in~~according to claim 23,  
~~characterized in that a~~57, wherein the solderable metal is selected from the group consisting of  
copper, nickel, silver, and gold ~~is used as the solderable metal for the connection elements (11,~~  
~~21).~~

59. 25.—The electromechanical connection as ~~claimed in~~according to claim 19,  
~~characterized in that~~53, wherein the electrically conductive grains (23-1) of the microcapsules  
(23-1, 23-2) are formed from an electrically conductive metal core which is covered with a solder  
material.

60. 26.—The electromechanical connection as ~~claimed in claim 25, characterized in~~  
~~that~~according to claim 59, wherein the electrically conductive metal core is comprised of copper  
~~is used as material for the electrically conductive metal core.~~

61. 27.—The electromechanical connection as ~~claimed in claim 25 and/or 26, characterized~~  
~~in that tin is used as solder material for~~according to claim 59, wherein the covering of the core is  
comprised of tin.

62. 28.—The electromechanical connection as ~~claimed in one of claims 1 to 27,~~  
~~characterized in that~~according to claim 35, wherein the electrically conductive grains (23-1) of  
the microcapsules (23-1, 23-2) have a diameter of the order of magnitude of 10  $\mu\text{m}$ , preferably  
~~less than~~about 10  $\mu\text{m}$ .

63. 29.—The electromechanical connection as ~~claimed in~~according to claim 27, characterized in that61, wherein the tin covering of the core has a thickness of the order of magnitude ofabout 200 nm.

64. 30.—The electromechanical connection as ~~claimed in one of claims 1 to 18,~~ characterized in thataccording to claim 46, wherein the layers of solder which are applied to the connection elements (11, 21) have a thickness of the order of magnitude ofabout 10  $\mu\text{m}$ , preferably less than 10  $\mu\text{m}$ .

65. 31.—A method for producing the electromechanical connection as ~~claimed in one of~~ claims 1 to 30, characterized in that, afteraccording to claim 35, comprising compressing the microcapsules (23-1, 23-2) embedded in an adhesive (24) or a polymer film have been introduced between electronic circuit system (10) and substrate (20), the microcapsules (23-1, 23-2) between the connection elements (11, 21) of the circuit system (10) and of the substrate (20) are compressed under such a force such that the dielectric (23-2)coating on electrically conductivethe grains (23-1) situated between connection elements (11, 21) which face one another is broken open, and producing the soldered joint (25 to 28) in each case between those areas of the grains (23-1) which face the connections (11, 21) and the connections (11, 21) is produced by diffusion soldering.

66. 32.—The method as ~~claimed in~~according to claim 31, characterized in that65, further comprising applying layers of solder metal (25, 27) are applied to connection elements (11, 21) in a thickness which is such that, during a diffusion-soldering process between metals of the electrically conductive grains (23-1) or grains (23-1) in the form of metallized insulators and the solder metal, the solder metal is completely converted into an intermetallic phase (26, 28).

67. ~~33.~~ The method as ~~claimed in~~according to claim 31, ~~characterized in that, when~~  
~~using~~65, wherein the microcapsules (23-1, 23-2) whosehave electrically conductive grains (23-1)  
~~eonsist~~consisting entirely of solder metal, and connection elements (11, 21) which are free of  
solder metal ~~on electronic circuit system (10) and substrate (20), the~~further comprising selecting  
a thickness of the connection elements (11, 21) ~~is selected in such a way~~so that sufficient  
material is available for thea transformation process during the diffusion soldering.

68. ~~34.~~ The method as ~~claimed in~~according to claim 31, ~~characterized in that, when~~  
~~using~~65, wherein the microcapsules (23-1, 23-2) whosehave electrically conductive grains (23-1)  
~~comprise~~comprising an electrically conductive metal core covered with a solder metal, and  
wherein the connection elements (11, 21) ~~which are free of solder metal on electronic circuit~~  
system (10) ~~and substrate (20), further comprising selecting the thickness of the connection~~  
elements (11, 21) ~~and of the solder metal is selected in such a way that their material~~there is  
sufficient material, during the diffusion soldering; for thea transformation process ~~between~~  
~~connection element material and core metal having the solder metal.~~

69. The electromechanical connection according to claim 62, wherein the diameter of the  
microcapsules is less than 10  $\mu$ m.

70. The electromechanical connection according to claim 64, wherein the layers of solder  
have a thickness of less than 10  $\mu$ m.



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TO ALL WHOM IT MAY CONCERN:

Be it known that WE, Holger Huebner and Vaidyanathan Kripesh, citizens of Germany and India respectively, residing in Germany and India respectively, whose post office addresses are Hamsterweg 10, 85598 Baldham, Germany; and L-5/E Sarvamangala Colon, Ind-Chennai 600083, Ashok Nagar, India, respectively, have invented an improvement in:

ELECTROMECHANICAL CONNECTION BETWEEN  
ELECTRONIC CIRCUIT SYSTEMS AND SUBSTRATES,  
AND METHOD FOR PRODUCING THIS CONNECTION

of which the following is a

SPECIFICATION

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] The present invention relates to an electromechanical connection between electronic circuit systems and substrates in accordance with the preamble of patent claim 1 and to a method for its production in accordance with patent claim 31.

BACKGROUND OF THE INVENTION

[0002] In the context of the present invention, the term electronic circuit systems is understood as meaning solid-state circuit systems, in particular integrated semiconductor circuits. Specifically, the term system indicates, for example in an integrated

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COMPARISON

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semiconductor circuit, the semiconductor material body which holds the electronic functional circuit elements, such as transistors, diodes, capacitors, etc., and the metallic conductor tracks and connection elements which are situated on this body and connecting the functional circuit elements. The connection elements may be flat applications of metal, known as pads, or spherical metallic elements, known as bumps. Further, in the context of the present invention, the term substrates is understood as meaning circuit boards, such as printed circuits or printed-circuit boards. Substrates of this type also have connection elements of the above-mentioned type, generally in the form of pads.

~~[0003] The connection elements may be flat applications of metal, known as pads, or spherical metallic elements, known as bumps.~~

~~[0004] In the context of the present invention, the term substrates is understood as meaning circuit boards, such as printed circuits or printed-circuit boards. Substrates of this type also have connection elements of the above-mentioned type, generally in the form of pads.~~

~~[0005] It is known to produce electromechanical connections of the type under discussion by means of an adhesive which contains electrically conductive grains. An electromechanical connection of this type is explained below with reference to Fig. 1.~~

~~[0006] Fig. 1 diagrammatically depicts an electronic circuit system 10, for example an integrated semiconductor circuit, which is electrically and mechanically connected to a substrate 20, for example a printed-circuit board. Connection elements in the form of pads are present on the circuit system 10, and connection elements 21, which are likewise in the form of pads, are present on the substrate 20.~~

[0003] ~~{0007}~~ It is known to produce electromechanical connections of the type under discussion by means of an adhesive which contains electrically conductive grains. An electromechanical connection of this type is ~~explained~~ described below with reference to ~~Fig. 1.~~ Figure 1, which ~~Fig. 1~~ diagrammatically depicts an electronic circuit system 10, ~~for example~~ e.g., an integrated semiconductor circuit, which is electrically and mechanically connected to a substrate 20, ~~for example~~ such as a printed-circuit board. Connection elements in the form of pads are present on the circuit system 10, and connection elements ~~21, which are likewise in the form of pads,~~ 21 which are also in the form of pads are present on the substrate 20. The circuit system 10 and the substrate 20 are connected to one another using the ~~flip~~ Flip-chip ~~Chip~~ technology ~~Technology~~ in such a manner that the pads 11 and 21 come to lie facing one another, with an adhesive 24, which contains electrically conductive grains 22 and 23 and is indicated by dot-dashed lines, between them. The adhesive 24 may, ~~for example,~~ be a polymer, ~~while~~ and the conductive grains may consist of silver.

[0008] ~~In a connection of the above-mentioned type, electrically conductive grains, which are in this case denoted by 22, come to lie in the lateral spaces between the pads 11 and 21, and conductive grains which are denoted by 23 come to lie in the vertical spaces between pads 11 and 21 which face one another.~~

[0004] ~~{0009}~~ ~~In a connection of the above-mentioned type, the electrically conductive grains, which are in this case denoted by 22, come to lie in the lateral spaces between the pads 11 and 21, and conductive grains which are denoted by 23 come to lie in the vertical spaces between pads 11 and 21 which face one another.~~ Pressing the circuit system 10 and substrate 20 together ensures that the electrically conductive grains 23 between pads

11 and 21 which face one another come into electrically conductive contact with these pads, thus producing an electrical connection between circuit system 10 and substrate 20. ~~By contrast, the~~ The electrically conductive grains 22 in the lateral spaces between pads 11 and 21 do not come into electrically conductive connection with the pads, ~~so that in this respect~~ hence there is no short-circuiting connection between pads. An electrical connection of the type described is anisotropically conductive, in that an electrically conductive connection is produced in the vertical direction by electrically conductive grains ~~22~~ 2223 between pads 11 and 21 which face one another, but is not produced in the lateral direction by electrically conductive grains 22 in lateral spaces between pads 11 and 21.

[0005] ~~{0010}~~ To indicate that the electrically conductive grains 23 between pads 11 and 21 which face one another can be deformed during compression, they are diagrammatically indicated in an oval shape, ~~while the~~ The grains 22 in the lateral spaces between pads 11 and 21 remain undeformed and are therefore diagrammatically indicated in the shape of a circle.

~~{0011}~~ In the type of electromechanical connection described above, ~~the following conditions have to be satisfied for reliable operation.~~

[0006] ~~{0012}~~ Firstly, ~~the adhesive 24,~~ In the type of electromechanical connection described above, the following certain conditions have to be satisfied for reliable operation. First, during setting and ~~when~~ while the circuit system 10 and substrate 20 are operating, the adhesive 24 has to develop sufficiently high shrinkage forces to ensure permanent compression ~~and therefore, in order to provide~~ a reliable mechanical

connection between circuit system 10 and substrate 11. However, adhesives do not generally have good properties in terms of adhesion and resistance to moisture, and consequently a connection of this type is not sufficiently reliable. Particularly in the event of fluctuating thermal loads, high shear forces may arise in the adhesive ~~join~~joint, with the result that the adhesive may break open and, ~~as a result~~, the electrical connection through the electrically conductive grains 23 may be broken. Furthermore, moisture which ~~penetrates~~may penetrate into the ~~join~~may joint, when heated, may cause entire areas of the circuit system 10 to break away from the substrate 20. These drawbacks ~~are~~may be offset by the ~~advantage that~~ adhesives that do not need to be structured.

[0007] ~~{0013}~~ ~~Secondly~~Second, the amount of electrically conductive grains 22, 23 in the adhesive 24 must be sufficiently large to ensure that there is at least one electrically conductive grain 23 between pads 11, 21 which face one another, in order to guarantee an electrically conductive connection. On the other hand, the amount of these grains must not be so high that there is a risk of electrical short circuits being caused by electrically conductive grains 22 in lateral spaces between pads 11, 21. This problem assumes greater importance as ~~As~~ the level of integration increases and ~~therefore~~ the electrically conductive structures become smaller, as do the distances between them on integrated semiconductor circuits and matching structures on substrates connected to the circuits, such as for example printed-circuit boards, ~~the latter problem becomes increasingly~~ important.

~~{0014}~~ ~~As the level of integration increases and therefore the electrically conductive structures become smaller, as do the distances between them on integrated semiconductor~~

~~circuits and matching structures on substrates connected to the circuits, such as for example printed circuit boards, the latter problem becomes increasingly important.~~

[0008] ~~[0015]~~ To counteract this problem, it is known from "Flip Chip Technologies" by John H. Lau, McGraw-Hill, 1996, pages 289-299, to use microcapsules which are embedded in an adhesive and comprise electrically conductive grains and a dielectric surrounding them, for example in the form of an insulating plastic. A microcapsule of this type comprising an electrically conductive grain 22-1 (or 23-1) and a dielectric 22-2 (or 23-2) surrounding it is illustrated on an enlarged scale in ~~Fig.~~ Figure 2.

[0009] ~~[0016]~~ In an electromechanical connection using conductive grains surrounded by a dielectric in an adhesive also requires the circuit system 10 and the substrate 20 to be pressed together, as shown in ~~Fig.~~ Figure 1. As a result of the pressure which is generated by this operation and the setting of the adhesive 24, the microcapsules 23-1, 23-2 between pads 11, 21 which face one another are compressed, ~~with the result that. This results in the dielectric 23-2 is being broken open and, as a result, an electrically~~ conductive connection is formed via the electrically conductive grains 23-1. This state of affairs is diagrammatically illustrated in Fig. Figure 3 in the form of a deformed microcapsule 23-1, 23-2 between two pads 11, 21. Although in an electromechanical connection of this type produced by means of microcapsules of the type microcapsules described above the problem of lateral electric short circuits via microcapsules 22-1, 22-2 situated in the lateral spaces between pads 11, 21 is virtually eliminated, the problems described above in connection with the adhesive remain as before.

~~[0017]~~ Although in an electromechanical connection of this type produced by means of microcapsules of the type described above the problem of lateral electric short circuits via microcapsules 22-1, 22-2 situated in the lateral spaces between pads 11, 21 is virtually eliminated, the problems described above in connection with the adhesive remain as before.

### SUMMARY OF THE INVENTION

~~[0010]~~ ~~[0018]~~ The present invention is based on the object of providing provides an electromechanical connection of the type under discussion which, is both mechanically and electrically stable and prevents electric short circuits even with fine electrically conductive structures on electronic circuit systems and substrates, is both mechanically and electrically stable and prevents electric short circuits. Specifically, With an electromechanical connection of the generic type, this object is achieved, according to the invention, by the measures given in the characterizing part of patent claim 1. is formed between electronic circuit systems and substrates which are mechanically connected. The electrical connection elements which face one another on the electronic circuit system and substrate are connected in an electronically conductive manner by means of microcapsules which are in the form of grains coated with a dielectric which is broken open on its areas which face the electrical connection elements. At the exposed areas of the grains an electrically conductive soldered joint is formed between the exposed areas of the grains and the electrically conductive connection elements which face these areas.

~~{0019}~~ With an electromechanical connection of the generic type, this object is achieved, according to the invention, by the measures given in the characterizing part of patent claim 1.

~~{0020}~~ A method for producing an electromechanical connection according to the invention is characterized by the measures given in patent claim 31.

~~{0021}~~ Refinements of the electromechanical connection according to the invention and of the method according to the invention form the subject matter of corresponding subclaims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

~~{0011}~~ ~~{0022}~~ The present invention is ~~explained~~described in ~~more~~greater detail below on the basis of exemplary embodiments in ~~conjunction~~connection with the figures of the ~~drawing~~drawings, in which:

Figures 1 to 3 ~~show the~~illustrate known ~~embodiments~~features of the invention which have already been ~~explained~~described above, ~~hereinabove~~;

Fig. 4 ~~shows a diagrammatic illustration, corresponding to that shown in Fig. 1,~~  
of ~~Figure 4 illustrates~~ an electromechanical connection in order to explain embodiments in accordance with the invention, corresponding to that shown in Fig. 1, of Figure 1 but which embodiment is in accordance with the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

~~{0012}~~ ~~{0023}~~ The essence of the invention is to be seen as residing in the fact that In accordance with the present invention, a metallic solder joint is produced at least at the



locations of the electrical connections, in addition to a compressive connection to produce the electrical connection between an electronic circuit system and a substrate, a metallic solder joint is produced at least at the locations of the electrical connections.

~~[0024]~~ In Fig. 4, on the basis of which ~~embodiments of the invention are explained~~, identical elements to those shown in Figures 1 to 3 are provided with identical reference symbols.

~~[0013]~~ ~~[0025]~~ As has already been ~~explained~~, In Figure 4, on the basis of which embodiments of the invention are explained, identical elements to those shown in Figures 1 to 3 are provided with identical reference symbols. As explained in connection with reference to Fig. Figure 1, the arrangement shown in Fig. Figure 4 is likewise illustrates an electromechanical connection between an electronic circuit system 10, 10 (for example an integrated semiconductor circuit system), and a substrate 20, 20 (for example an electrical printed-circuit board). Electronic circuit system 10 and substrate 20 ~~one~~ also have the connection elements in the form of pads 11 and 21.

~~[0014]~~ ~~[0026]~~ The A purely mechanical connection ~~takes place~~ occurs by means of the adhesive 24 which is indicated by dot-dashed lines, for example a polymer, ~~in which,~~ ~~however,~~ However, unlike ~~in the~~ known embodiment shown in ~~Fig. Figure~~ 1, it is not purely metallic electrically conductive particles 22, 23, but rather microcapsules 22-1, 22-2, 23-1, 23-2 which are suitable for a soldering operation that are embedded.

Embodiments of these microcapsules are explained in more detail below.

~~[0015]~~ ~~[0027]~~ It should be noted that the invention is not restricted to embodiments used with an adhesive 24 to produce the purely mechanical connection between electronic

circuit system 10 and substrate 20. Embodiments in which a connection is produced by means of a soldering operation without adhesive, which is described in even more detail below, are also possible. This can take place by means of pads 11, 21 which are inactive for the intended electronic operation of electric circuit system 10 and substrate. In this context, the term "inactivity" means that pads of this type are not electrically connected to electronic functional elements in electronic circuit system 10 or on or in substrate 20.

~~[0028] A first embodiment of a soldered joint in the context of the invention is explained below.~~

~~[0016] [0029] In this~~A first embodiment of a soldered joint in the context of the invention is explained below.~~present embodiment~~invention, the microcapsules comprise electrically conductive grains 22-1, 23-1 which are covered with a dielectric 22-2, 23-2 and may consist of a metal selected from the group consisting of copper, nickel, silver, gold, a solderable metal alloy or an insulator, for example tin oxide, which is covered with an electrically conductive metal, ~~for example~~e.g., silver. The way in which microcapsules of the latter type can be produced is known, for example, from "JOURNAL OF MATERIALS SCIENCE" 28 (1993), pages 5207-5210.5210 which is incorporated herein by reference. The dielectric 22-2, 23-2 used may be an insulating enamel, which may also act as a soldering flux.

~~[0030] The dielectric 22-2, 23-2 used may be an insulating enamel, which may also act as a soldering flux.~~

~~[0017] [0031]~~For the soldering operation, layers of solder 25, 27, for which a metal selected from the group consisting of tin, indium, gallium, or a metal alloy with a low

melting point may be used, are provided on the pads 11, 21 in order to produce the electrically conductive connection between electronic circuit system 10 and substrate 20. The layers of solder 25, 27 are preferably produced by selective electroless deposition on the pad surfaces, so that it is possible to produce sufficiently planar surfaces.

[0018] ~~[0032]~~ In accordance with the method according to the present invention, microcapsules 22-1, 22-2, 23-1, 23-2, which are embedded in the adhesive 24 or a polymer film, which is not specifically shown in ~~Fig-~~Figure 4, are introduced between the electronic circuit system 10 and the substrate 20, ~~and they~~20. They are then compressed together under such a force that the dielectric 23-2 of microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another is broken open. After ~~the~~ compression, the arrangement is heated to a temperature which ~~lies~~is above the melting point of the solder material of the layers of solder 25, 27. In the process, the molten solder comes into contact with material of the electrically conductive grains 23-1 of the microcapsules 23-1, 23-2, 2 and a metallic bond ~~with~~having good electrical conductivity is produced.

[0019] ~~[0033]~~ Microcapsules 22-1, 22—2 in lateral spaces between pads 11, 21 remain unaffected by the compression operation and therefore their dielectric 22-2 remains intact, ~~with the~~. The result of this is that lateral short circuits are prevented. Therefore, the electromechanical connection according to the invention is anisotropically conductive in the sense explained above.

~~[0034]~~ It is particularly advantageous if a diffusion soldering method is used for the soldering. In this method, a metallic bond which is able to withstand high temperature is produced using a low melting solder as a result of the solder metal forming an

intermetallic phase, which is able to withstand high temperatures and is very mechanically stable, with high melting metals which are to be connected. In the process, the low melting solder metal is completely transformed, i.e. passes completely into the intermetallic phase. A soldering method of this type is known per se, for example from US-A 5 053 195.

[0020] [0035] For this method, It is particularly preferred~~It is particularly advantageous if~~  
a diffusion-soldering method is used for the soldering. In this method, a metallic bond  
which is able to withstand high temperature is produced using a low-melting solder as a  
result of the solder metal forming an intermetallic phase, which is able to withstand high  
temperatures and is very mechanically stable, with high-melting metals which are to be  
connected. In the process, the low-melting solder metal is completely transformed, i.e.  
passes completely into the intermetallic phase. A soldering method of this type is known  
per se, for example from US-A 5 053 195, disclosed in United States Patent No.  
5,053,195, wherein the layers of solder 25, 27 have a thickness of the order of magnitude  
of about 10  $\mu\text{m}$ , preferably of less than 40  $\mu\text{m}$ . ~~They~~about 10  $\mu\text{m}$ , and consist, for  
example, of tin. The electrically conductive grains 23-1 or the metallic layers of grains in  
the form of metallized insulators, and if appropriate the pads 11, 21, consist, for  
~~example~~e.g., of copper or nickel. When contact is made between the metal of the grains  
during the diffusion-soldering method, the tin is completely transformed into  
intermetallic phases, which are denoted by 26, 28 in ~~Fig.~~Figure 4. As has ~~already~~been  
explained above, the joint which is formed in the process has a significantly higher  
melting point than the solder metal and better mechanical properties, such as high tensile  
strength and freedom from creep. It is important~~In a development of the invention, it is~~

essential in a soldering process of this type that a single layer of microcapsules is situated between the pads 11, 21 and the pad surfaces are sufficiently planar. Then, all the microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another are compressed, so that their electrically conductive grains 23-2 or their electrically conductive parts come into contact with the solder metal.

~~[0036] In a development of the invention, it is essential in a soldering process of this type that a single layer of microcapsules is situated between the pads 11, 21 and the pad surfaces are sufficiently planar. Then, all the microcapsules 23-1, 23-2 situated between pads 11, 21 which face one another are compressed, so that their electrically conductive grains 23-2 or their electrically conductive parts come into contact with the solder metal.~~

[0021] ~~[0037]~~ The A single-layer structure can be produced particularly successfully if – as stated above – the microcapsules 22-1, 22-2, 23-1, 23-2 are previously embedded in a polymer film. The waymanner in which films with embedded microcapsules of this type can be built up and produced in detail is known per se, for example from taught in 1992 "IEEE", pages 473 to 480 and 487 to 491. A film of this type ensures the lateral insulation of the microcapsules 22-1, 22-2, 23-1, 23-2 and can act as a spacer. Shaped parts which match the surfaces which are to be connected can be produced. The adhesive 24 can then be dispensed with, if appropriate.

[0022] ~~[0038]~~ It should be mentioned once again that the configuration described above is not specifically illustrated in Fig.Figure 4. Also, soldered joints between pads 11, 21 which are inactive in the sense mentioned above and microcapsules 23-1, 23-2 without any adhesive 24 being present are not specifically illustrated in Fig.Figure 4. However,

in Fig-Figure 4 it would be possible, for example, for the two pads 11, 21 shown on the right-hand side of the drawing to be regarded as "inactive" pads and for the two pads 11, 21 situated on the left-hand side of the drawing to be regarded as "active" pads.

~~{0039}~~ In a further embodiment of the invention, it is possible to use microcapsules 22-1, 22-2, 23-1, 23-2 which at least in part consist of a solder metal.

~~{0040}~~ According to one variant of this embodiment, the electrically conductive grains 22-1, 23-1 consist entirely of solder metal, in which case a metal selected from the group consisting of tin, indium, gallium or a soft solder alloy can be used as solder metal.

~~{0041}~~ In this case, a solderable metal which may be a metal selected from the group consisting of copper, nickel, silver or gold is used as material for the pads 11, 21 of the electronic circuit system 10 and substrate 20.

{0023} {0042} In a further preferred embodiment of the present invention, it is possible to use microcapsules 22-1, 22-2, 23-1, 23-2 which at least in part consist of a solder metal. According to a~~According to one~~ variant of this embodiment, the electrically conductive grains 22-1, 23-1 consist entirely of solder metal, in which case a metal selected from the group consisting of tin, indium, gallium or a soft-solder alloy can be used as solder metal. In this case, a solderable metal which may be a metal selected from the group consisting of copper, nickel, silver or gold is used as material for the pads 11, 21 of the electronic circuit system 10 and substrate 20. Also in this embodiment to, the electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 are surrounded by a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. As well as its insulating action in the lateral direction, which has been

~~explained above, this~~ This layer of insulating enamel additionally prevents in particular electrically conductive grains 22-1 in the lateral spaces between pads 11, 21 of electronic circuit system 10 and substrate 20 from flowing together when heated during the soldering process and therefore prevents short circuits in the lateral direction.

[0024] ~~[0043]~~ Since the solder material of the electrically conductive grains 23-1, 23-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 becomes liquid during the soldering process, and therefore the layer of insulating enamel breaks more easily, the pressure required to break open this layer between pads 11, 21 which face one another is not as high as in the first embodiment of microcapsules ~~which was explained above~~. When the solder material makes contact with the material of the pads 11, 21, the soldered joint is formed, and therefore electrical and mechanical contact is made.

[0025] ~~[0044]~~ Since the microcapsules 22-1, 22-2 in the lateral spaces between pads are not compressed, their layers of insulating enamel 22-2 remain intact. When using an adhesive 24, these microcapsules are held together either by ~~this~~ the adhesive, or when embedded in a polymer film ~~in the sense explained above~~, and cannot flow out.

Therefore, in this embodiment ~~too~~, the diffusion-soldering method explained above is particularly advantageous. The electrically conductive grains 22-1, 23-1 of the microcapsules 22-1, 22-2, 23-1, 23-2 may, for example, consist of tin and the pads 11, 21 of electronic circuit system 10 and substrate 20 may consist of copper or nickel. If the electrically conductive grains of the microcapsules have a diameter of less than 10  $\mu\text{m}$ , the tin is completely transformed into the intermetallic phase 26, 28 when contact is made between the solder metal and the pad metal. In turn, an electromechanical connection with a melting point which is significantly higher than that of the solder metal, and

therefore excellent mechanical properties, such a high tensile strength and freedom from creep; is formed.

~~[0045] Electrically conductive grains with a small diameter of the order of magnitude of 10  $\mu$ m and preferably less than 10  $\mu$ m are advantageous for a number of reasons.~~

~~[0046] Firstly, the thicker the electrically conductive grains, the longer the process of chemical transformation takes during the diffusion soldering. For example, with a diameter of 40  $\mu$ m the reaction takes over half an hour. With diameters of less than 10  $\mu$ m, the reaction time is of the order of magnitude of minutes.~~

~~[0047] Secondly, the pads 11, 21 have to be sufficiently thick to be able to provide sufficient metal for the transformation reaction. When using electrically conductive grains having the preferred diameters, there is relatively little solder metal available, so that correspondingly a small amount of pad metal needs to be available for complete transformation.~~

~~[0026] [0048] Thirdly Electrically conductive grains with a small diameter of the order of magnitude of 10  $\mu$ m and preferably less than 10  $\mu$ m are advantageous for a number of reasons. FirstFirstly, the thicker the electrically conductive grains; the longer the process of chemical transformation takes during the diffusion soldering. For example, with a diameter of 40 about 40  $\mu$ m the reaction takes over half an hour. With diameters of less than 10  $\mu$ m, about 10  $\mu$ m the reaction time is of the order of magnitude of minutes. SecondSecondly, the pads 11, 21 have to be sufficiently thick to be able to provide sufficient metal for the transformation reaction. When using electrically conductive grains having the preferred diameters; there is relatively little solder metal available, so~~



~~that correspondingly a~~ so that a correspondingly small amount of pad metal needs to be available for complete transformation. Third, small diameters of the electrically conductive grains are of benefit to finely structured contacts, which ~~is~~are advantageous in particular for integrated semiconductor circuits with a high level of integration. ~~Fourthly~~Fourth, the diameter of the electrically conductive grains determines the thickness of the soldered joint. Thin soldered joints have a better fracture behavior. With a thickness of less than about 5  $\mu\text{m}$ , the joint has ~~an~~an elastic action when bent, whereas if its thickness is greater than about 10  $\mu\text{m}$  it becomes brittle, so that stress cracks may easily form.

[0027] ~~{0049}~~ ~~As~~In a modification ~~to~~of the embodiment described above, the electrically conductive grains 22-1, 22-2 of the microcapsules 22-1, 22-2, 23-1, 23-2 may not consist entirely of solder metal, but rather may consist of a metal core which is covered with solder metal. This may, for example, be a copper core which is covered with a layer of ~~tin~~tin solder. If the tin solder is deposited electrolessly in a tin exchange bath, the top layer of the copper core is replaced by a correspondingly thin layer of tin. A typical thickness of the layer of tin is of the order of magnitude of about 200 nm.

[0028] ~~{0050}~~ The use of electrically conductive grains of this type, including ~~for~~their use in the mechanical and electrical connection of objects, is ~~known per se, for example from~~disclosed in 1996 "Electronic Components and Technology Conference", pages 565-570, 570 which describes an electrically conductive adhesive material which comprises a conductive filler powder, which is covered with a metal with a low melting point (solder metal), a thermoplastic polymer, and further minor organic additives. The filler grains are coated with the metal of a low melting point which, when producing a connection

between objects, is melted in order to produce a metallurgical bond between adjacent filler grains and between filler grains and metallic connection elements on the objects which are to be connected. A connection of this type corresponds to the arrangement shown in ~~Fig-~~Figure 1. In this case, ~~too~~however, the problems explained above with regard to the adhesive formed by the polymer and with regard to the amount of electrically conductive grains used, ~~are~~ may be encountered.

[0029] ~~[0051]~~ As ~~in~~In the two embodiments ~~explained~~discussed above, electrically conductive grains 22-1, 22--2 ~~of this type~~ are covered with a dielectric 22-2, 23-2 in the form of a layer of insulating enamel. It should be noted that the fact that the electrically conductive grains may for their part be of two-part form is not specifically illustrated in Figures 2 to 4.

[0030] ~~[0052]~~ One advantage of electrically conductive grains 22-1, 23-1 in the form of metal cores which are covered with solder metal is that the soldering process, which is once again preferably in the form of the diffusion-soldering process, takes place very quickly and precisely; on account of the overall very thin layer of solder. A further advantage is that even in microcapsules 22-1, 22-2 in the lateral spaces between pads 11, 21, which are therefore not in contact with pads 11, 21, the solder reacts with the core metal and is transformed into an intermetallic phase. Therefore, microcapsules of this type, ~~too~~, are firmly stable at temperatures which lie well above the melting point of the solder, since they can no longer become liquid.

[0031] ~~[0053]~~ Furthermore, on account of the low thickness of the layers of solder of the electrically conductive grains and the resultant relatively small quantity of solder metal,

the thickness of the pads 11, 21 can be reduced, since a correspondingly small quantity of pad material is required for complete transformation of the quantity of solder. A further reason for using layers of solder of small thickness is that it is ~~no longer~~not necessary for the pads to be raised, since the solder of the electrical conductive grains ~~can no longer~~cannot "run out" when the layer of insulating enamel breaks open, since the low layer thickness means that the solder adheres to the surface of the metal core, providing good wetting of the latter. Accordingly~~For the above reasons~~, in all the microcapsules 22-1, 22-2, 23-1, 23-2, both those in lateral spaces between pads 11, 21 and those between pads which face one another, it is no longer possible for any liquid solder, which leads to short circuits, to form at operating temperatures of the arrangement. Hence ~~electromechanical~~Electromechanical contact with the pads 11, 21 results from the reaction of the solder of the electrically conductive grains 23-1, 23-2 with the metal of the pads 11, 21.

~~[0054]~~ ~~For the above reasons~~, in all the microcapsules 22-1, 22-2, 23-1, 23-2, both those in lateral spaces between pads 11, 21 and those between pads which face one another, it is no longer possible for any liquid solder, which leads to short circuits, to form at operating temperatures of the arrangement.

~~[0055]~~ ~~Electromechanical~~ contact with the pads 11, 21 results from the reaction of the solder of the electrically conductive grains 23-1, 23-2 with the metal of the pads 11, 21.

[0032] ~~[0056]~~ A further advantage in particular in the embodiments with electrical conductive grains 22-1, 23-1 comprising metal other than solder metal and layers of solder 25, 27 on the pads 11, 21, as well as electrically conductive grains comprising

metal cores covered with a layer of solder, is that it is possible to produce particularly thin solder layers, which can be controlled accurately, during the diffusion-soldering method, in the form of intermetallic phases 26, 28.

[0033] ~~{0057}~~ In the embodiments described above, the microcapsules 22-1, 22-2, 23-1, 23-2, 2 (apart from the variant involving the embedding in a polymer film,) can be processed with an insulating liquid, which may be the above-mentioned adhesive 24 or a flux, to form a paste. In the case of the adhesive, it is possible to combine the advantages of an adhesive bond and of a soldered joint. This adhesive bond ensures additional mechanical stability, and the soldered joint ensures reliable electrical connection.

[0034] ~~{0058}~~ To summarize, ~~it should be pointed out once again that,~~ according to the present invention, it is possible to achieve a creep-resistant connection, since during the preferred diffusion soldering the solder material, (as a thin layer on the microcapsules or the connection elements on the electronic circuit system and the substrate,) is completely changed into the intermetallic phase, i.e. no residues of solder material remain.

~~Furthermore, the~~ The thin layers of solder material ensure that the soldering process takes place relatively quickly. Furthermore, the large quantity of microcapsules which is possible even with small connection element structures means that reliable electrical connection in combination with good thermal conduction and —on (on account of the mechanical soldered joint via the soldered microcapsules—) a significantly more reliable mechanical connection compared to a pure adhesive bond is ensured. Finally, high thermal stability of electromechanical connection is also ensured, ensured since the overall connection operation can be designed in such a way that no residues, such as for

example insulating residues of metal oxides, glass or ceramic or binder, remain in the connection.

~~{0059} Furthermore, the large quantity of microcapsules which is possible even with small connection element structures means that reliable electrical connection in combination with good thermal conduction and —on account of the mechanical soldered joint via the soldered microcapsules— a significantly more reliable mechanical connection compared to a pure adhesive bond is ensured.~~

~~{0060} Finally, high thermal stability of electromechanical connection is also ensured, since the overall connection operation can be designed in such a way that no residues, such as for example insulating residues of metal oxides, glass or ceramic or binder, remain in the connection.~~

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WE CLAIM:

35. 1.—An electromechanical connection between electronic circuit systems (10) and substrates (20), in which ~~an~~comprising the electronic circuit system (10) and a substrate (20) are mechanically connected ~~fixedly~~ to one another, and electrical connection elements (11, 21) which face one another on the electronic circuit system (10) and the substrate (20) are in each case connected in an electrically conductive manner by means of microcapsules (23-1, 23-2), and in which the microcapsules (23-1, 23-2) are formed ~~by~~from grains (23-1) which are coated with a dielectric (23-2) and which are at least in part ~~are~~partially electrically conductive, ~~characterized in that~~wherein the dielectric (23-2) of the microcapsules (23-1, 23-2) is broken open at least on its areas which face the electrical connection elements (11, 21), and at the ~~correspondingly~~provide exposed areas of the grains, (23-1) and an electrically conductive soldered joint (25 to 28) is formed in each case between the exposed areas of the grains (23-1) and the electrically conductive connection elements (11, 21), which in each case face these areas, of the electronic circuit system (10) and of the substrate (20), respectively.

36. 2.—The electromechanical connection as ~~claimed in~~according to claim 1, ~~characterized in that~~35, wherein the mechanically ~~fixed~~mechanical connection between the electronic circuit system (10) and substrate (20) is made by means of an adhesive (24).

37. 3.—The electromechanical connection as ~~claimed in~~ claims 1 and 2, ~~characterized in that~~according to claim 36, wherein the adhesive (24) used is formed from a polymer.

38. 4. ~~The electromechanical connection as claimed in one of claims 1 to 3,~~  
~~characterized in that~~according to claim 36, wherein the microcapsules (23-1, 23-2) are  
embedded in the adhesive (24).

39. 5. ~~The electromechanical connection as claimed in~~according to claim 4,  
~~characterized in that~~35, wherein the mechanically fixed mechanical connection between  
electronic circuit system (10) and substrate (20) is formed by a soldered joint between  
connection elements (11, 21) which are inactive in the intended electronic functioning of  
electronic circuit system (10) and substrate (20).

40. 6. ~~The electromechanical connection as claimed in one of claims 1 to 5,~~  
~~characterized in that~~according to claim 35, wherein the grains are electrically conductive  
metal grains (23-1) which are selected from the group of metals consisting of copper,  
nickel, silver, and gold and are covered with a dielectric (23-2) are used as microcapsules  
(23-1, 23-2).

41. 7. ~~The electromechanical connection as claimed in one of claims 1 to 5,~~  
~~characterized in that~~according to claim 35, wherein the grains are electrically conductive  
metal grains (23-1) of a solderable metal alloy, ~~which are covered with a dielectric (23-~~  
2), are used as microcapsules (23-1, 23-2).

42. 8. ~~The electromechanical connection as claimed in one of claims 1 to 5,~~  
~~characterized in that~~according to claim 35, wherein the grains are metallized; insulating  
grains (23-1) which are covered with a dielectric (23-2) are used as microcapsules (23-1,  
23-2).

43. 9. ~~The electromechanical connection as claimed in~~according to claim 8,  
~~characterized in that~~42, wherein the grains are silver-plated tin oxide grains are used as  
metallized, insulating grains (23-1).

~~44. 10.~~ The electromechanical connection as ~~claimed in one of claims 6 to 9,~~  
~~characterized in that~~according to claim 35, wherein the dielectric is an insulating enamel  
is used as the dielectric (23-2) of the microcapsules (23-1, 23-2).

~~45. 11.~~ The electromechanical connection as ~~claimed in claim 10, characterized in~~  
~~that a soldering flux is used as~~according to claim 44, wherein the insulating enamel is a  
soldering flux.

~~46. 12.~~ The electromechanical connection as ~~claimed in one of claims 1 to 11,~~  
~~characterized in that~~according to claim 35, wherein the electrically conductive soldered  
joint (25 to 28) between the connection elements (11, 21) of electronic circuit system (10)  
and substrate (20) is formed by ~~soldering of~~ layers of solder (25, 27) which are provided  
on the connection elements (11, 21) to form intermetallic phases (26, 28) comprising  
material of the electrically conductive grains (23-1) of the microcapsules (23-1, 23-2) and  
the layers of solder (25, 27).

~~47. 13.~~ The electromechanical connection as ~~claimed in~~according to claim 12,  
~~characterized in that~~46, wherein a metal selected from the group consisting of ~~tin~~tin,  
indium and gallium is used as the material for the layers of solders (25, 27).

~~48. 14.~~ The electromechanical connection as ~~claimed in~~according to claim 12,  
~~characterized in that~~46, wherein a metal alloy ~~with~~having a low melting point is used as  
the material for the layers of solder (25, 27).

~~49. 15.~~ The electromechanical connection as ~~claimed in~~according to claim 13 or  
14, ~~characterized in that~~47, wherein the layers of solder (25, 27) ~~are~~comprise layers of tin  
which have been deposited selectively ~~and without using~~the use of an electric current.

~~50. 16.~~ The electromechanical connection as ~~claimed in one of claims 1 to 15,~~  
~~characterized in that~~according to claim 35, wherein the electrical connection elements



comprise a metallic material which is matched to the metallic material of the conductive grains (23-1) of the microcapsules (23-1, 23-2) is used as material for the connection elements (11, 21) of electronic circuit system (10) and substrate (20).

51. 17. The electromechanical connection as ~~claimed in claim 16, characterized in that~~ according to claim 50, wherein (23-1) of the microcapsules (23-1, 23-2) is used as material for the connection elements (11, 21) of electronic circuit system (10) and substrate (20) comprise a metal selected from the group consisting of copper or and nickel is used as material for the connection elements (11, 21).

52. 18. The electromechanical connection as ~~claimed in one of claims 1 to 17, characterized in that~~ according to claim 35, wherein the microcapsules are provided in a single layer, of said microcapsules (23-1, 23-2) being of a uniform size and embedded in a polymer film are provided.

53. 19. The electromechanical connection as ~~claimed in one of claims 1 to 5, characterized in that~~ according to claim 35, wherein the grains are electrically conductive metal grains (23-1) which are covered with an insulating enamel (23-2) and, which grains at least in part consist of a solder metal are used as microcapsules (23-1, 23-2).

54. 20. The electromechanical connection as ~~claimed in~~ according to claim 19, characterized in that 53, wherein the electrically conductive grain (23-1) of the microcapsules (23-1, 23-2) consist entirely of solder metal.

55. 21. The electromechanical connection as ~~claimed in~~ according to claim 19 or 20, characterized in that a 53, wherein the solder metal is selected from the group consisting of tin, indium, and gallium ~~is used for the electrically conductive grains (23-1).~~

56. ~~22.~~—The electromechanical connection as ~~claimed in claim 19 or 20,~~  
~~characterized in that~~according to claim 53, wherein the solder metal is a soft-solder alloy  
is used for the electrically conductive grains (23-1).

57. ~~23.~~—The electromechanical connection as ~~claimed in one of claims 19 to 22,~~  
~~characterized in that~~according to claim 53, wherein a solderable metal is used for the  
connection elements (11, 21) of electronic circuit system (10) and substrate (20).

58. ~~24.~~—The electromechanical connection as ~~claimed in~~according to claim 23,  
~~characterized in that~~ a57, wherein the solderable metal is selected from the group  
consisting of copper, nickel, silver, and gold ~~is used as the solderable metal for the~~  
connection elements (11, 21).

59. ~~25.~~—The electromechanical connection as ~~claimed in~~according to claim 19,  
~~characterized in that~~53, wherein the electrically conductive grains (23-1) of the  
microcapsules (23-1, 23-2) are formed from an electrically conductive metal core which  
is covered with a solder material.

60. ~~26.~~—The electromechanical connection as ~~claimed in claim 25, characterized in~~  
~~that~~according to claim 59, wherein the electrically conductive metal core is comprised of  
~~copper is used as material for the electrically conductive metal core.~~

61. ~~27.~~—The electromechanical connection as ~~claimed in claim 25 and/or 26,~~  
~~characterized in that tin is used as solder material for~~according to claim 59, wherein the  
covering of the core is comprised of tin.

62. ~~28.~~—The electromechanical connection as ~~claimed in one of claims 1 to 27,~~  
~~characterized in that~~according to claim 35, wherein the electrically conductive grains (23-  
1) of the microcapsules (23-1, 23-2) have a diameter of the order of magnitude of 10  $\mu\text{m}$ ,  
preferably less than about 10  $\mu\text{m}$ .

~~63. 29.~~ The electromechanical connection as ~~claimed in~~ claim 27, characterized in that 61, wherein the tin covering of the core has a thickness of the order of magnitude of about 200 nm.

~~64. 30.~~ The electromechanical connection as ~~claimed in one of claims 1 to 18~~, characterized in that according to claim 46, wherein the layers of solder which are applied to the connection elements (11, 21) have a thickness of the order of magnitude of about 10  $\mu\text{m}$ , preferably less than 10  $\mu\text{m}$ .

~~65. 31.~~ A method for producing the electromechanical connection as ~~claimed in one of claims 1 to 30~~, characterized in that, after according to claim 35, comprising compressing the microcapsules (23-1, 23-2) embedded in an adhesive (24) or a polymer film have been introduced between electronic circuit system (10) and substrate (20), the microcapsules (23-1, 23-2) between the connection elements (11, 21) of the circuit system (10) and of the substrate (20) are compressed under such a force such that the dielectric (23-2) coating on electrically conductive the grains (23-1) situated between connection elements (11, 21) which face one another is broken open, and producing the soldered joint (25 to 28) in each case between those areas of the grains (23-1) which face the connections (11, 21) and the connections (11, 21) is produced by diffusion soldering.

~~66. 32.~~ The method as ~~claimed in~~ claim 31, characterized in that 65, further comprising applying layers of solder metal (25, 27) are applied to connection elements (11, 21) in a thickness which is such that, during a diffusion-soldering process between metals of the electrically conductive grains (23-1) or grains (23-1) in the form of metallized insulators and the solder metal, the solder metal is completely converted into an intermetallic phase (26, 28).

67. ~~33.~~ The method as ~~claimed in~~ according to claim 31, characterized in that, when using ~~65~~, wherein the microcapsules (23-1, 23-2) whose ~~have~~ electrically conductive grains (23-1) ~~consist~~ consisting entirely of solder metal, and connection elements (11, 21) which are free of solder metal on electronic circuit system (10) and substrate (20), ~~the~~ further comprising selecting a thickness of the connection elements (11, 21) is selected in such a way so that sufficient material is available for ~~the~~ a transformation process during the diffusion soldering.

68. ~~34.~~ The method as ~~claimed in~~ according to claim 31, characterized in that, when using ~~65~~, wherein the microcapsules (23-1, 23-2) whose ~~have~~ electrically conductive grains (23-1) ~~comprise~~ comprising an electrically conductive metal core covered with a solder metal, and wherein the connection elements (11, 21) which are free of solder metal on electronic circuit system (10) and substrate (20), further comprising selecting the thickness of the connection elements (11, 21) and of the solder metal is selected in such a way that ~~their material~~ there is sufficient material, during the diffusion soldering, for ~~the~~ a transformation process ~~between connection element material and core metal having the~~ solder metal.

69. The electromechanical connection according to claim 62, wherein the diameter of the microcapsules is less than 10  $\mu\text{m}$ .

70. The electromechanical connection according to claim 64, wherein the layers of solder have a thickness of less than 10  $\mu\text{m}$ .

## ABSTRACT OF THE DISCLOSURE

In an electromechanical connection between electronic circuit systems (10) and substrates (20), these components are mechanically connected fixedly to one another, their electrical connection elements (11, 21) are connected to one another in an electrically conductive manner via microcapsules (23-1, 23-2), which comprise grains (23-1) which are coated with a dielectric (23-2) and, at least in part, are electrically conductive, and there is an electrically conductive soldered joint (25 to 28) between microcapsules (23-1, 23-2) with broken-open dielectric (23-2) and the electrical connection elements (11, 21).

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